EVALUATION OF HYPOTHETICAL REMEDIATION STRATEGY PRESENTED IN STRATUS CONTINGENT VALUE STUDY

ILLINOIS RIVER WATERSHED

Prepared by

Anchor QEA, LLC
305 West Grand Avenue, Suite 300
Montvale, New Jersey 07645

In Conjunction with

Timothy J. Sullivan, Ph.D.
E&S Environmental Chemistry, Inc.
2161 N.W. Fillmore Ave
Corvallis, Oregon 97339-0609

Frank Coale, Ph.D.
College of Agricultural and Natural Resources
University of Maryland
1109 H.J. Patterson
College Park, Maryland 20742

March 2009

EXHIBIT P

UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex. rel. W.A. DREW EDMONDSON, in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA and OKLAHOMA SECRETARY OF THE ENVIRONMENT, J.D. Strong, in his capacity as the TRUSTEE FOR NATURAL RESOURCSE FOR THE STATE OF OKLAHOMA,

Plaintiffs,

v.

TYSON FOODS, INC., TYSON POULTRY, INC., TYSON CHICKEN, INC., COBB-VANTRESS, INC., AVIAGEN, INC., CAL-MAINE FOODS, INC., CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTION, LLC, GEORGE'S INC., GEORGE'S FARMS, INC., PETERSON FARMS, INC., SIMMONS FOODS INC., and WILLOW BROOK FOODS, INC.,

Defendants.

Case No. 05-CV-329-GKF-PJC

EXPERT REPORT OF

John P. Connolly, Ph.D., P.E., B.C.E.E.

Frank Coale, Ph.D.

Timothy J. Sullivan, Ph.D.

March 2009

EXHIBIT P

TABLE OF CONTENTS

1 INTRODUCTION 1

2 THE PLAINTIFF'S ASSUMPTIONS UNDERLYING THE HYPOTHETICAL REMEDIATION STRATEGY ARE FLAWED 4

2.1 The Objective to Remediate to 1960's Conditions Lacks Supportable Data and is Impractical 4

2.2 The Conclusion that the Current Water Quality in the Watershed is Poor and Needs Substantive Remediation is Inaccurate 6

2.3 The Assumption that Poultry Litter is Primarily Responsible for the Water Quality Impacts that Do Exist is Flawed 11

2.4 The Elimination of Poultry Litter Will Not Result in the Conditions Predicted by the Plaintiffs' Models 12

2.5 Stratus Provides No Basis for the 40 Year Acceleration Proposed to Occur Due to Alum Application 13

3 THE PLAINTIFF FAILED TO EVALUATE THE PRACTICALITY, EFFICACY, AND COLLATERAL IMPACTS OF THE HYPOTHETICAL REMEDIAL STRATEGY 15

3.1 Implementation Issues with Alum Applications to Water Bodies 16

3.2 Alum Treatment to Reduce Phosphorus Loads in the Illinois River and Lake Tenkiller 19

3.2.1 Alum Treatment of the Illinois River 20

3.2.2 Alum Treatment of Lake Tenkiller 21

3.2.3 Permitting and Stakeholder Concerns 22

4 ALUM APPLICATION TO SOILS IN THE ILLINOIS RIVER WATERSHED 24

5 REFERENCES 29

List of Figures

Figure 2-1. Total phosphorus concentrations as a function of flow at Watts.

EXHIBIT P

LIST OF ACRONYMS AND ABBREVIATIONS

CV	Contingent Valuation
DO	Dissolved Oxygen
NDEPS	National Discharge Elimination Permit System
P	Phosphorus
SRP	Soluble Reactive Phosphorus
TOC	Total Organic Carbon
TP	Total Phosphorus
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant

1 INTRODUCTION

Stratus Consulting ("Stratus") was hired on behalf of the State of Oklahoma to support its claim that actions and activities of 14 named Defendants have damaged the Illinois River system and Lake Tenkiller. Specifically, Stratus was tasked with estimating the monetary value of alleged phosphorus caused damages to the Illinois River system and Lake Tenkiller. To develop this estimate, Stratus conducted a Contingent Valuation (CV) study. This study used a Survey to elicit from the public a monetary value of alleged aesthetic and ecosystem injuries. The Survey was administered to a sampling of adults living in Oklahoma. Alleged water quality problems were described to the individuals being surveyed ("respondents"), a supposed method to solve the alleged problems was presented, and the respondents were asked to vote for or against the "solution" given that a one-time tax would be levied to pay for the solution. The tax amount was varied, but the Survey concluded that the public was willing to pay $184.55 per household to achieve the benefits claimed in the Survey. This amount, when multiplied by 1,352,878 households, produced an estimated CV of $249,673,635 (the 95% limits around this estimate were presented as $224,198,942 to $275,148,328).

The "solution" presented to survey respondents is a hypothetical scenario that is described in the passage below from the Stratus Report (Chapman et al. 2009):

> *The solution introduced in the survey was a program to treat land and waters in the Illinois River watershed with alum, a substance that bonds with phosphorus and makes it unavailable to plants, including algae. The survey noted that many states have successfully used a similar program to reduce algae. The survey narrative explained that with alum treatments, it would take about 10 years for the river and 20 years for the lake to return to 1960 conditions, compared with 50 and 60 years, respectively, if alum was not applied. Hence, alum treatments would reduce the period over which the injuries would be present by 40 years for both the river and lake. Respondents were told that if alum treatments were implemented, the cost would be a one-time tax added to their state income tax bill next year.*

EXHIBIT P

> *The presentation of the alum treatment program allowed respondents to make a choice about a well-defined, realistic tradeoff. Either they could greatly reduce the injury and pay the tax for the alum treatments or accept the natural recovery without the alum treatment and use their money for other purposes.*

As the above passage states, the objective of the hypothetical scenario is to restore the lake and river to conditions that supposedly existed in 1960. The respondents were told that if poultry litter application ceased the river and lake would return to these conditions in 50 and 60 years, respectively, but that alum application would dramatically shorten the recovery time.

Unfortunately, the respondents were not given a true picture of what the current water quality conditions are or what the phosphorus sources to that water are. Furthermore, respondents were not made aware that the presented "solution" had no scientific or technical basis (i.e., there was no site-specific analysis to support the claims made in the Survey).[1] Because the respondents were given inaccurate and faulty information about the status of the Illinois River Watershed and the major sources of nutrients to the streams in the Illinois River Watershed and to Lake Tenkiller, the Survey is not valid and its CV estimate is therefore meaningless. Specifically, the Survey is fatally flawed for the following reasons:

- It mischaracterizes the aesthetic and ecosystem conditions in the Illinois River and Lake Tenkiller.
- It falsely states that attaining the conditions that existed in 1960 is a possible and desirable goal given the large changes that have occurred in the human population in this watershed, and assumes that we know what the conditions were in 1960 that need to be attained.

[1] Stratus discusses in their report the correlation between the amount the respondent is willing to pay for the remediation and the stated efficacy of the proposed remedial action. In other words, their own study indicated that the more effective in accelerating recovery the remedial action was believed to be by the respondent, the more a respondent would be willing to pay in a tax to fund the remediation. Thus, the net result of Plaintiffs' over-exaggeration of the possible effectiveness of their proposed solution would be to over-exaggerate how much those respondents would be willing to pay to implement that solution (Chapman et al. 2009; page 6-7).

- It ignores the many sources of phosphorus that would not be impacted by the presented "solution" and gives the false impression that poultry litter is the sole, or even a major, reason for the alleged injuries.
- It does not acknowledge that there has been no work done by the Plaintiffs to evaluate the feasibility, efficacy, or collateral impacts (e.g., negative effects on biota, water quality, general stakeholder reaction, etc.) of the presented "solution".
- It does not acknowledge the lack of a scientific basis for the claim that water quality in the Illinois River and Lake Tenkiller would be greatly and rapidly improved by alum application.
- It does not acknowledge that fertilizer application is needed to maintain the livestock industry in Oklahoma and that commercial fertilizers would have to be used in place of poultry litter if land application of poultry litter is no longer permitted.

2 THE PLAINTIFF'S ASSUMPTIONS UNDERLYING THE HYPOTHETICAL REMEDIATION STRATEGY ARE FLAWED

2.1 The Objective to Remediate to 1960's Conditions Lacks Supportable Data and is Impractical

The Stratus Survey uses the 1960 condition as a "baseline" for recovery. The Survey questions and narrative state that the conditions of the river and lake in 1960 were desirable. This contention is flawed for two reasons:

1. Little data are available to assess the condition of the river or lake in 1960 and therefore, it is not possible to determine whether the purported high quality condition existed in 1960.
2. Changes have occurred in the watershed during the last 50 years, including deforestation and urbanization, both of which affect water quality. The human population has increased dramatically, and this would be expected to affect water quality. Consequently, reaching 1960's conditions, even if we knew what they were, may be impossible given the changes that have occurred in the watershed, many of which might be irreversible.

Besides a Survey taken in 1960-1961 that analyzed fish populations, dissolved oxygen, temperature, plankton, and phytoplankton species (Summers 1961; see Horne 2009 for discussion), no other water quality data from the early 1960's on Lake Tenkiller have been found. The United States Environmental Protection Agency's (USEPA's) STORET database contains no other lake-wide datasets before the mid-1970's. Although some conclusions can be drawn from the 1960-1961 data related to phytoplankton species, fish populations, temperature, and dissolved oxygen (see Horne 2009), this dataset does not include the measurements typically used to assess trophic level (i.e., chlorophyll-*a*, Secchi depth, and phosphorus concentrations). The Stratus Survey indicates that in the 1960's, "the water was clear enough so you could see down about 10 feet." Assuming this statement refers to the riverine section of the reservoir, no data to support it have been found. In fact, the earliest measurements of Secchi depth found in historical databases occurred in the mid-1970's and indicate Secchi depths of about four feet in the riverine portion of the reservoir. Deeper Secchi depths were measured in the lacustrine area, but such depths have occurred both historically (mid-1970's) and currently (Plaintiff's data 2004 – 2008). Given the natural

EXHIBIT P

variability in Secchi depth and the lack of the historical data, it is impossible to conclusively state that Secchi depths in any portion of the lake in the 1960's were deeper than they are today (see Horne 2009 for further discussion).

The Stratus Survey also presents photos[2] to contrast what the lake "most likely" looked like in the 1960's and today (Chapman et al. 2009; Survey Card G). These photos are used to "demonstrate" that the 1960's lake water was clear and blue, as opposed to green and murky. Greenish tints in water can be caused by algal growth (measured as concentration of chlorophyll-*a*) and, therefore, high chlorophyll-*a* concentrations may result in greenish-tinted water. However, because we have no data to determine what the chlorophyll-*a* levels were during the 1960's, we do not know with certainty what the lake "most likely" looked like in the early 1960's. Therefore, photos taken during some period of time other than the 1960's cannot be used to show what the lake "most likely" looked like during the 1960's. It is not possible to know with certainty the aesthetic quality of the lake water in the 1960's and whether this condition is desirable as a "baseline" to which the lake needs to "recover."

Similar to the lake, the 1960's data on the river are sparse. A search of the United States Geological Survey (USGS) and USEPA (STORET) databases indicates little data in the 1960's. In fact, the Stratus Survey tells the respondents that "around 1960" the river was "usually clear" and there was "little algae on the bottom of the river." However, there are little to no data to support these statements.[3] In fact, analysis of the limited phosphorus data that are available show that the concentrations in the Illinois River at Watts in 1969 are in the ranges measured from 2004 – 2008, within similar flow regimes (Figure 2-1).

The Plaintiffs' photos show a clear, flowing river with clean rocks as the "usual" river in the early 1960's (Chapman et al. 2009; Survey Cards E and F), but these images are unsupported

[2] It should also be noted that the photos used by Stratus in their survey are misleading in that they imply these conditions exists along all of the river or within all of the lake most of the time. Algal blooms are episodic and are isolated to areas most conducive to algae growth. Although the narrative mentions the episodic nature of blooms, it is not conveyed in the images shown to the Survey respondents.

[3] USGS and STORET databases contain very few records for primary indicators of eutrophication phosphorus (P) and dissolved oxygen (DO) for the Illinois River watershed from 1958 - 1970. One Illinois River location, USGS 7195500, has six P and six DO records in 1969, and one tributary location, Sager Creek, has seven P and 45 DO records for 1968 – 1969. No P or DO records were found in either database for 1958 - 1967.

by any historical data – we have little information on what the river looked like "usually" in the 1960's. In fact, given the general state of wastewater treatment plant (WWTP) technology and septic systems in the 1960's, one could easily argue that the river in the 1960's was most likely in worse condition than it is today because of changes in loading due to human sewage.[4] Because of this lack of information, it is impossible to conclusively state, as the Plaintiffs have done, that the 1960's condition was desirable.

Besides the lack of data to determine the state of the system in the 1960's, using the 1960's as a baseline ignores important changes that have occurred on the watershed since that time, including increased human population, and associated deforestation and urbanization. Grip (2008) showed considerable urban development in this watershed over the last ~30 years. Sullivan (2009) presented data that suggest that the human population in the Illinois River Watershed has more than tripled since 1960. Between 1990 and 2007 the human population within the watershed increased from about 168,000 to 297,000 people, a 77% increase over a period of less than two decades. Deforestation and urbanization typically cause detrimental effects on water quality and can result in potentially irreversible water quality impacts (see Connolly 2009, Section 2 and Sullivan 2009, Section III.5 for discussion). Urbanization causes increased non-point source pollution and increased WWTP discharges. Even if it were determined that the 1960's condition was desirable, these changes on the watershed may have rendered that condition unattainable and unrealistic.

2.2 The Conclusion that the Current Water Quality in the Watershed is Poor and Needs Substantive Remediation is Inaccurate

A key assumption of the Stratus Survey is that the current water quality in the Illinois River watershed is poor. However, this assumption is based on flawed analyses performed by the Plaintiffs' consultants. Chapter 4 of Chapman et al. (2009) reviews the basis for this

[4] WWTP practices and the use of phosphorus detergents in the 1960's would have resulted in historically higher phosphorus concentrations in WWTP discharges than today. Passage of the Clean Water Act in 1972 and the banning of phosphorus detergents in the mid-1990's had significant impact on the water quality of the waters of the United States. In particular, the enforcement of the Clean Water Act caused many WWTPs to upgrade to secondary and even tertiary treatment levels, while the phosphorus detergent ban resulted in significant reductions to phosphorus concentrations in WWTP influents and likewise, their effluents (Litke 1999).

assumption throughout its narrative describing the Survey. On Page 4-10, their Survey states:

> *Algae also float in the water and can make the water look murky. The water in the river used to be clear most of the time.* ***Now, during summer, the water is sometimes murky because of algae.*** (emphasis added)

This last bolded sentence is allegedly based on statements made by Dr. Stevenson in his report. However, upon review of the cited pages in Stevenson's report, the only mention of "murky" water is made on Page 22 of Stevenson (2008):

> *Planktonic algal biomass was approximately equal during spring 2007 and summer 2006. During summer 2006, planktonic algal biomass ranged from 0.2 to 15 µg chl a/L with a median of 1.2 and 25th and 75th quartiles of 0.65 and 2.15 µg/L. During spring 2007, planktonic algal biomass ranged from 0.1 to 20 µg chl a/L with a median of 1.45 and 25th and 75th quartiles of 0.8 and 2.35 µg/L. Based on this range of conditions, waters were usually relatively clear with less than 1.45 µg chl a/L, but would sometimes be murky with chlorophyll as high as 20 µg/L.*

This passage indicates that occurrences of planktonic algal biomasses that would result in "murky" conditions are rare and Stevenson, himself, indicates the waters are "usually relatively clear." In fact, the 75^{th} quartile measurements reported by Stevenson (2008) for 2006 and 2007 were both in the range of 2 µg/L, which is relatively low. Connolly (2009) analyzed the same data and found that instances of nuisance planktonic algal levels that would cause "murky" conditions were rare:

> *The measurements of benthic algae conducted in the Oklahoma portion of the Illinois River and its tributaries by the Plaintiffs' consultants…show that nuisance densities are rare. In summer 2006, the maximum density was 13.8 µg chlorophyll-a/cm^2 and about 95% of the stations had densities less than 10 µg chlorophyll-a/cm^2. In spring 2007, the maximum density was 33.5 µg chlorophyll-a/cm^2, but almost 90% of the stations had densities less*

> *than 10 μg chlorophyll-a/cm². Densities above 10 μg chlorophyll-a/cm² occurred principally in tributaries and frequently downstream of WWTPs. Only one station in the Illinois River in each sampling year had a value greater than 10.*

In fact, the photo shown on the left hand panel of Survey Card F may very well be the exception more so than the normal condition for benthic algal biomass, based on the Plaintiffs' dataset from 2006 and 2007. Furthermore, based on Connolly's (2009) analyses, where conditions are similar to those shown on that left hand panel in the Survey, the most likely cause of those conditions would be WWTP discharge, rather than land application of poultry litter.

Besides the alleged aesthetic issues supposedly caused by benthic biomass, the Stratus Survey makes a statement about fish species in the river, again citing Dr. Stevenson as the basis for the statement (Chapman et al. 2009; Page 4-10):

> *Algae on the bottom and in the water have changed the types of plants and animals that live in the river. There are now fewer of the smallmouth bass, other fish, and small plants than used to live in the river. In some places, the algae uses up most of the oxygen in the water. Low oxygen causes fish to grow more slowly. And in some places, some species have probably disappeared completely because of the algae.*

Again, this statement is based on flawed analyses and conclusions drawn by Stevenson (2008). Connolly (2009) analyzed the same biological dataset in the Illinois River Watershed as Stevenson (2008) and found that the fisheries were not damaged and the diversity measured may not be a function of water quality nor may it be representative of the system, given the sampling methods followed:

> *…the fish community within the Illinois River Watershed is not highly degraded due to water quality impacts. While diversity is low in some locations, this is not unexpected due to the size of the streams (smaller streams will support fewer species). Stevenson also observed a direct*

> *relationship between fish species number and watershed size with fewer species in smaller watersheds (Stevenson 2008, Section 4.3.2.1., p. 40). There are limited data available on habitat parameters, so habitat quality can not be assessed at this time. However, it is possible that sites with lower IBI and/or diversity index scores may be more impacted by habitat availability than water quality degradation. Jester et al. (1992) reported that the majority of Oklahoma fish species are more sensitive to habitat degradation than they are to water quality degradation. Finally, the protocol used to sample fish may underestimate the diversity of fish within the watershed.* (Connolly 2009)

Regarding the fisheries in the lake, the Stratus Survey relies upon analyses and conclusions from Drs. Cooke and Welch (Chapman et al. 2009; Page 4-11):

> *In many parts of the lake where the oxygen and temperature were ideal for smallmouth bass and other types of fish people catch, there is now so little oxygen during the summer that these areas are no longer ideal for these fish. Under such conditions, smallmouth bass and the other types of fish grow slower and there are fewer of them.*

But these statements are gross approximations of general habitat conditions made by Drs. Cooke and Welch in their report (2008). Work done by Connolly (2009) indicates these conclusions are inaccurate because they do not account for life history strategies of these species. Specifically:

> *Black bass are a littoral zone species, occupying steep rocky shorelines or areas with macrophyte coverage, while the habitat squeeze model is based on water quality within the pelagic zone. The habitat squeeze model does not represent or account for the numerous refuges available within the littoral zone, especially at the mouths of tributaries and in coves. Smallmouth bass in lakes and reservoirs typically prefer drop-offs, rocky shoals, and wave swept littoral regions (Edwards et al. 1973; Hubert and Lackey 1980; Winemiller and Taylor 1987). Spotted bass also prefer areas with steep, rocky shorelines (McMahon et al. 1984). Adult black bass typically feed in the littoral zone,*

> *with smallmouth bass and spotted bass feeding on crustaceans and fish within the interstitial spaces in cobble and largemouth bass feeding primarily on prey found within vegetated habitats (Werner et al. 1977; McMahon et al. 1984; Weaver et al. 1997).* (Connolly 2009)

In fact, the Survey completely ignores the impacts that occurred as a result of the construction of the dam along the Illinois River to form the lake, which most likely had significant impacts on habitat and species diversity (see Connolly 2009 for further discussion).

Furthermore, the Stratus Survey ignores the available data that indicate Lake Tenkiller is a "premier" fishery. Connolly (2009) reviews the available data related to the quality of the Lake Tenkiller fishery:

> *…Lake Tenkiller typically ranks in the top five in Oklahoma in the number of largemouth bass caught per hour in reservoirs >1,000 acres (ODWC 2003b, 2006). According to ODWC, high quality lakes produce at least 60 bass per hour of electrofishing with 15 or more of those fish at least 14 inches (356 mm) long. Lake Tenkiller was in the high quality category for every year data were available between 1993 and 2006.…Lake Tenkiller has been cited as one of the "state's premier fisheries" with fishing for black bass, crappie, and catfish (McNeff 2008).*

These points are never acknowledged by Chapman et al. (2009). This leaves the survey taker to assume the present quality of the fishery from the biased information provided in the Stratus Survey.

Finally, the Stratus Survey spends time discussing water clarity in the lake. It claims that the water is less clear today than it was in the 1960's. However, work by Horne (2009) indicates that Secchi depths (which is a measurement of water clarity) in the lake are no different today than they were historically, given natural variability and uncertainty in the datasets.

EXHIBIT P

The Plaintiffs' own data show that the conditions in the Illinois River are not as dire as the Survey proposes. In fact, analyses of Plaintiffs' datasets, combined with other agencies' data, indicate that the system is, in fact, improving: phosphorus concentrations in the river are coming down (most likely due to improvements in WWTP discharges; see Connolly [2009] and Sullivan [2009] for further discussion).

In summary, the Stratus Survey makes broad statements regarding the Illinois River Watershed's alleged injuries based on work performed by Drs. Cooke, Welch, and Stevenson. However, these statements are based on flawed analyses and conclusions. The Plaintiffs' own data do not support many of the claims of injury purported by their own consultants. Because the Survey results are based on inaccurate statements regarding the current state of ecological conditions in the Illinois River Watershed, the results of that survey that pertain to willingness-to-pay are invalid.

2.3 The Assumption that Poultry Litter is Primarily Responsible for the Water Quality Impacts that Do Exist is Flawed

A critical assumption of the Stratus Survey is that poultry litter is primarily responsible for the alleged injuries in the watershed. The Plaintiffs' consultants put forth this argument in many of their reports (Engel 2008; Fisher 2008; Olsen 2008). In fact, the remedial alternative that is presented in the Survey would have to assume that poultry litter application is close to the sole contributor of phosphorus to the waters of the Illinois River Watershed if it were to actually be as effective as Chapman et al. (2009) claims it will be. But, the majority of the data collected by the Plaintiff and others indicates that other phosphorus sources, mainly WWTP discharges, control the aesthetics in the rivers and lake. Extensive analyses performed by Connolly (2009) and Sullivan (2009) show that elevated phosphorus concentrations in the river are most commonly found downstream of WWTPs and WWTPs contribute the majority of the phosphorus load that would be responsible for algal growth during the summer season. Connolly (2009) also presents substantive analyses that show the conclusion drawn by Fisher (2008) and Olsen (2008) regarding poultry litter as a dominant source of phosphorus to the system is not supported by the Plaintiffs' own data.

EXHIBIT P

Chapman et al. (2009) also ignored the contribution of many potential phosphorus loadings, such as urban runoff, WWTP dischargers, and the contribution of phosphorus from other livestock such as cattle. Connolly (2009), Sullivan (2009), and Jarman (2008) all review other sources of phosphorus to this system that can not be ignored. For example, Connolly (2009) found that the cattle population in the Illinois River Watershed contribute more water-extractable-phosphorus than the poultry population These analyses refute the assumption that poultry litter is primarily responsible for any alleged aesthetic problems in the watershed and in fact, the WWTPs most likely control the water quality during the season in which most algal blooms occur (i.e., summer).

2.4 The Elimination of Poultry Litter Will Not Result in the Conditions Predicted by the Plaintiffs' Models

The Stratus Survey depends on the modeling results of Drs. Wells and Engel to predict how long it will take the river and lake to "recover" to 1960's conditions once poultry litter application is ceased. However, these predictions are inaccurate because these models have not been properly calibrated and in some cases, not properly developed. Dr. Engel's model, which is extensively reviewed by Dr. Bierman (2009), does not represent the response of river water quality to any changes in land surface processes. Dr. Engel's model is merely an exercise in matching one empirical equation to another and does not provide a systematic representation of the response of the river water quality to any change in land management practices. Furthermore, Bierman (2009) concludes that Dr. Engel's watershed modeling was based on an inappropriate tool for predicting watershed-scale phosphorus loads in the Illinois River Watershed. Bierman (2009) also concluded that Dr. Engel's watershed model was based on an inappropriate mass balance construct and could be calibrated based on nonsensical data. Consequently, any alleged response simulated in this system to poultry litter cessation is inaccurate.

Dr. Wells' model of Lake Tenkiller is also flawed. First, this model does not accurately represent the water quality conditions (specifically dissolved phosphorus and chlorophyll-*a* concentrations) in the lake due to poor calibration (see Connolly 2009, Section 8). Second, this model's future predictions of lake water quality rely on the results of Dr. Engel's watershed model future predictions of loadings from the rivers into the lake. In other words, the results from Dr. Engel's watershed model are "fed into" Dr. Wells' lake model as loadings to Lake Tenkiller. Consequently, even if the lake model had been well calibrated, its future predictions would be flawed due to the inaccuracies in Dr. Engel's watershed modeling results.

As a result, the statements by Stratus in their Survey that the river and lake would recover to 1960's conditions in about 60 and 50 years, respectively, once poultry litter application was stopped, can not be supported. The models developed by the Plaintiffs can not provide an accurate measurement of this "time to recovery" as they are currently developed and applied.

2.5 Stratus Provides No Basis for the 40 Year Acceleration Proposed to Occur Due to Alum Application

The Stratus Survey represents that alum treatment would cause rapid improvement in water quality. The Survey states that by ceasing all poultry litter application and applying alum, the "recovery" of the river and lake would be accelerated by 40 years, meaning the river would now recover in 20 years and the lake, in 10. However, no scientific basis is given in Chapman et al. (2009) for this 40-year acceleration. The one citation given in the Chapman et al. (2009) report for alum treatment in the watershed (Cooke et al. 2005) actually states that alum treatment of reservoirs is uncommon and somewhat discourages direct application of alum in flowing rivers (see Section 3 of this report for further discussion). Nowhere in Cooke et al. (2005) is information provided that would allow one to quantify the acceleration of recovery using alum.[5] In reality, the Plaintiffs' consultants have not presented any results

[5] To support such a claim of effectiveness, acceptable scientific practice requires some level of modeling or empirical analyses to estimate the acceleration of recovery due to a remedial action. For example, Superfund requires a problem investigation (Remedial Investigation) and an analysis of viable alternatives (Feasibility Study) before any decisions regarding the best alternative is made. Without modeling or analyses, it is impossible to determine exactly how much any proposed alternative will alter the system or the path to recovery. And, because every system is different, it is not accurate to extrapolate results from one environmental system to another. Cooke et al. (2005) present a multi-step decision tree for choosing best restoration procedures for control of algae problems and call for some level of quantification of internal and external loading as the first step in determining restoration activities. To make the proper decision, Cooke et al. (2005) state that the lake manager will probably go through a decision process in which one or more of the 16 techniques presented by Cooke et al. will be chosen to apply to a specific lake for restoration. Cooke et al. continue to state that a different sequence in the decision tree may by needed for a given lake, depending on the economic, political, and social demands.

as to whether and to what extent alum treatment would improve water quality. Although they present this "remediation alternative" as "hypothetical," the extent of recovery acceleration that is suggested to result from alum treatment is significant and according to Chapman et al.' own analysis, the effectiveness of the remedial alternative influences a person's feelings towards its proposed implementation (Chapman et al. 2009; Page 6-7). One could argue that the Survey result may have been quite different if the alum treatment resulted in a recovery acceleration of only 10 years instead of 40. Without scientific evidence that the 40-year claim is valid, the entire Survey results are meaningless.

3 THE PLAINTIFF FAILED TO EVALUATE THE PRACTICALITY, EFFICACY, AND COLLATERAL IMPACTS OF THE HYPOTHETICAL REMEDIAL STRATEGY

The Stratus Survey did not consider or present the practicality, efficacy, and collateral impacts of its hypothetical remedial strategy and therefore provided the Survey respondents with an inaccurate and incomplete picture. Prior to representing alum treatment as a strategy of choice, a number of specific issues should have been considered. These issues are associated with the following basic questions:

1. Will alum treatment substantively reduce phosphorus load to Lake Tenkiller given the current understanding of the watershed?
2. Will alum treatment substantially reduce the concentration of phosphorus in Lake Tenkiller, and will that reduction in phosphorus concentration substantially change the biological conditions of the lake?
3. Can this treatment be adequately implemented?
4. What collateral impacts could be associated with alum treatment across a million acre watershed, the Illinois River, and Lake Tenkiller?

Alum has the potential to remove phosphorus available to algae by removing dissolved phosphorus from the water column and physically isolating and trapping phosphorus that would otherwise be released from sediments (Wisconsin DNR 2003). The alum used for phosphorus control is typically an aluminum sulfate. On contact with water, it quickly dissociates and the liberated aluminum forms aluminum hydroxide, an amorphous solid. The initial floc formation and subsequent settling to the lake sediment absorbs and encapsulates natural organic matter, free anions, and dissolved phosphorus, removing them from the water column (Lawler 2006). Phosphate binds to the aluminum hydroxide through anion ligand exchange, forming an insoluble compound that cannot be assimilated by algae.

Ideally, the alum flocs settle onto the sediment, forming an alum blanket that covers the lake bottom. If the alum dosage is designed to provide for active sorption of sediment phosphorus, the alum blanket is able to absorb phosphorus leaching from the sediment, preventing it from reaching the overlying water column and thereby inactivating the lake's internal cycling of phosphorus (Princeton Hydro 2005). New sediment introduced into the lake will eventually cover the floc layer. If the external loading of phosphorus has not been adequately managed, the incoming sediment will quickly diminish the floc layer's phosphorus retention capacity and render it ineffective.

3.1 Implementation Issues with Alum Applications to Water Bodies

Alum applications for treatment of phosphorus have shown both positive and negative results for both shallow, polymictic and deep, dimictic lakes (Cooke et al. 2005). Alum treatment is generally most effective in lakes where vertical transport is present and the primary source of phosphorus is internal cycling (Cooke et al. 2005). Alum application in a lake involves the distribution of solid or liquid alum to the surface or hypolimnion. General practice has shown that liquid application allows for the formation of more substantial flocs and a slightly lower change in water pH as compared to solid applications (Baird 1987; Cooke et al. 2005). Mechanically, surface applications are cheaper and easier than subsurface; however, surface applications often require buffering to avoid pH drops and associated toxicity to biota (Baird 1987, Cooke et al. 2005). Care must be taken during application to insure that alum and the buffer are applied in the proper corresponding dosages (Cooke et al. 2005). The alum and buffer cannot be pre-mixed on the distribution vessel because the precipitate clogs the pumps and piping (NALMS 2003; Baird 1987).

For phosphorus cycling from sediment to be effectively inactivated, the alum floc must cover the lake bottom. Rooted macrophytes can intercept the settling floc and prevent the alum from reaching the sediment. To diminish the impact of rooted plants, alum application needs to occur during the non-growing season, January through March. The colder water conditions during this time of year may reduce the phosphorus removal efficiency and pose additional aluminum toxicity concerns by limiting the coagulation and deposition of the alum floc (Cooke et al. 2005).

The success of alum treatment for phosphorus removal from the water column and phosphorus inactivation of the sediments depends on water body chemistry. In Delaware, alum treatment was initially recommended for Silver Lake to complement and enhance the efficacy of source reduction efforts (URS 2006). However, site-specific tests indicated that alum caused the water to become more acidic and residual aluminum concentrations exceeded the fresh water chronic and acute water quality standards (URS 2006). Based on these results, alum treatment was not recommended as a nutrient management tool for Silver Lake.

Cooke et al. (2005) indicated that phosphorus inactivation will be effective and long-lasting, without significant acute or chronic effects to biota in lakes with:

1. Significant reduction in external phosphorus loading
2. Alkalinity above 75 mg/L as $CaCO_3$
3. High levels of silica, calcium (Ca), sulfate (SO_4) and total organic carbon (TOC)

Alum treatment of soft-water lakes (< 35 mg/L as $CaCO_3$) requires the addition of a buffer to maintain a pH greater than 6 to avoid the formation of soluble, toxic forms of aluminum (Cooke et al. 2005). Potentially toxic levels of dissolved aluminum complexes may persist under certain pH conditions (NALMS 2004). Aluminum sulfate, used commonly in alum treatments, raises the concern that introduced sulfate ions may enhance sulfate reduction, which has the potential to stimulate mercury cycling and bio-methylation (Kerry et al. 2004, Branfireun et al.1999). Mercury methylation increases the extent to which mercury accumulates in the food chain of the lake. Based on these potential issues, prior to recommending alum treatment for Lake Tenkiller, the lake chemistry throughout the application area must be fully evaluated and characterized.

Baird (1987) and others (Princeton Hydro 2005) have stated that the chemistry of aluminum compounds in water is multifaceted and pH dependent, and therefore generalization about toxicity to biota is not possible. Because of the complexity of aluminum chemistry and toxicity, before alum treatment of a water body is considered, intensive nutrient and water analysis as well as an examination of the biotic communities must be conducted (Cooke et al. 2005). Cooke et al. (2005) recommended that long term monitoring and analysis of changes in biotic communities be parts of any treatment plan. Improper treatment can result in unforeseen outcomes. For instance, alum treatments that have successfully improved water clarity often resulted in increased macrophyte growth due to an increase in light availability (Cooke et al. 2005; Baird 1987). An increase in macrophyte populations may be unfavorable to recreational use of the water body and is a recognized possible side effect of alum treatment (Tetra Tech 2007).

The Stratus Survey told survey respondents that when alum is put into river or lake water that contains phosphorus, the alum attaches to the phosphorus to form harmless particles that fall to the bottom and blend into the dirt there (Chapman et al. 2009, Page A-15). This statement is false and leads the respondent to believe that the alum treatment has no adverse effects on the environment. However, several studies conducted to determine the impact of alum treatment on lake biota showed variable response of benthic invertebrate density and diversity to alum application (Steinman and Ogdahl 2008), including no effect (Narf 1990 as cited in Cooke et al. 1993; Water and Air Research 1999), increases (Narf 1990 as cited in Cooke et al. 1993), and declines in biotic density and diversity (Water and Air Research 1999). Morphological deformities have been reported in some benthic communities after alum treatments. The occurrence of these deformities points to possible accumulation of metals in the sediments as a result of anion absorption onto the alum floc (Water and Air Research 1999). In low pH conditions, acidification and dissolution of aluminum near the sediment water interface has shown to diminish the survival rates and possibly result in the extinction of some spring spawning fish and bottom dwelling amphibians (Harvey and Jackson 1995; McCormick et al. 1989; Rocco and Brooks 2000). Additionally, low doses of aluminum hydroxide can produce chronic, long term effects on fish, even at pH levels between 7.0 and 8.0 (Cooke et al. 2005). The improper application of alum has resulted in several instances of harm to fish. Alum treatment in Lake Morey, Vermont resulted in deleteriously high dissolved aluminum concentrations and a decrease in yellow perch prosperity (Smeltzer 2006). Alum treatment in Wapato Lake in Washington, Lake Hollingsworth in Florida and Pocotopaug Lake in Connecticut all resulted in substantial fish kills (Larson 2008; Fish and Wildlife Research Institute 2005; Hart 2007).

These issues must all be addressed before recommending alum treatment for the Illinois River and Lake Tenkiller and should have been part of the discussion with Survey respondents, but they were not. Because Survey respondents were not informed regarding the possibility of biological damage associated with alum application to the lake and river, their responses with respect to willingness-to-pay are invalid.

3.2 Alum Treatment to Reduce Phosphorus Loads in the Illinois River and Lake Tenkiller

In order to effectively limit phosphorus that is available as a nutrient in lake waters, both external and substantive internal sources must be controlled. Effectiveness of an alum treatment for inactivation of sediment phosphorus is dependent on first reducing external loads (Cooke et al. 2005). In the case of Lake Susser See in Germany, researchers determined there was no improvement in the trophic state after alum treatment because the amount of alum added was far too small compared to the external phosphorus load and recommend that as far as possible, external measures should be conducted prior to internal measures (Lewandowski et al. 2003). Lewandowski et al. (2003) showed that even thin layers of fresh sediments layering on an alum blanket resulted in high phosphorus release rates. If the alum layer is below the layer of fresh sediment, phosphorus from the sediment matrix in the fresh sediment can diffuse upwards and downwards. Modeling in Lewadowski et al.'s study indicated that in spite of the existing phosphorus binding capacity in the alum-phosphorus layer, it has little effect on the phosphorus release from newly deposited sediment even if the cover layer is thin. Burial of the alum treated sediment renders it increasingly ineffective in reducing phosphorus release from the freshly settled sediment (Lewandowski et al. 2003). Therefore, without significantly reducing the external sources of phosphorus to the Illinois River and Lake Tenkiller, any proposed alum treatment for long-term sediment inactivation would be ineffective.

The plaintiffs' consultants Drs. Cooke, Welch, Fisher, and Engel failed to properly account for all the potential phosphorus sources in the Illinois River Watershed and apparently provided Chapman et al. with the false belief that poultry litter was the dominant source of phosphorus to the river and reservoir. As discussed by Connolly (2009) and Sullivan (2009), WWTP are significant contributors of phosphorus, as is runoff from urban areas. Potentially important sources of phosphorus to the surface waters in the Illinois River Watershed that were not adequately considered by Plaintiffs' consultants in this case include cattle and other livestock, erosion, septic systems, and commercial fertilizer application (Sullivan 2009). Repeated alum applications over five years, as suggested in the Survey, would not treat all of these recurring, continuous phosphorus loads. The Stratus Survey stated that alum treatments would need to be done for five years to remove all of the excess phosphorus; this statement is false and misleading if all of the external phosphorus loads are not considered

EXHIBIT P

and reduced. Simply stopping poultry litter application and applying alum would not improve water quality. Before the entire watershed is treated with an application of alum, for which the long-term health impacts are not fully known, all substantive phosphorus sources would have to be controlled.

3.2.1 Alum Treatment of the Illinois River

During the Survey interview, respondents were told:

> *Alum would also remove phosphorus from river water flowing into Oklahoma from Arkansas. Dispensers would be put near the border to spread alum on the water when sensors find lots of phosphorus in it.* (Chapman et al. 2009)

This characterization of treatment of the Illinois River is misleading because respondents were not told of the difficulties associated with alum treatments in flowing streams. Cooke et al. (1993) states:

> *Stream treatments have been more difficult, have had negative impacts in some cases, and are more expensive than lake treatments.*

Cooke et al. (1993) present a case study in which alum was added to the Cuyahoga River above its entrance to Lake Rockwell in an attempt to reduce phosphorus loading to the lake. Alum was added during July to September, as a continuous flow from a perforated manifold spanning the main river channel. The treatment sequestered 50% to 60% of the soluble reactive phosphorus (SRP), but the total phosphorus (TP) loading to the reservoir was not significantly reduced. The aluminum hydroxide floc built up rapidly on the river bed near the point of injection and the pH fell to about 4.0 just below the manifold. Such a low pH, especially in association with high concentrations of dissolved aluminum, can be highly toxic to many forms of aquatic biota. Cooke et al. (1993) state that this method of phosphorus precipitation in streams is not recommended. Furthering this case study in Cooke et al. (2005), the authors state that as a follow-up treatment, compressed air was continuously injected at the application site, preventing floc build-up and benthic invertebrate mortality was less. Cooke et al. state that this type of application directly to the river failed because

EXHIBIT P

floc was not produced and therefore that the aluminum was not contained in a separate structure to protect benthos, and because the dose was too low for sufficient phosphorus removal (Cooke et al 2005).

3.2.2 Alum Treatment of Lake Tenkiller

Alum treatment of lakes to sequester sediment phosphorus is common; however, it is uncommon for reservoirs, such as Lake Tenkiller. Reservoirs commonly experience high rates of nutrient and sediment loading in their inflowing streams, leading to deposition of nutrient-rich materials over the floc that has accumulated on the sediment surface (Cooke et al. 2005). Dr. Welch (2008) stated in his deposition (Page 216, lines 8 – 20) his reservations with using alum treatment in Lake Tenkiller:

> *We don't have much track record with regard to reservoirs. The one reservoir that was treated, it didn't last very long. That could have been because it wasn't dosed heavily enough. So that would take a lot more investigation and deliberation to decide what kind of benefit that might have…Plus the fact it's kind of a rule of thumb you don't want to try and control internal loading if you still have high input from outside.*

The deposition of incoming solids and phosphorus is enhanced in Lake Tenkiller because river inflows dive to the hypolimnion as water moves towards the lacustrine region (Connolly 2009; Cooke and Welch 2008). This deposition could greatly impact the initial and long-term effectiveness of alum treatment. Moreover, the movement of organic matter and other chemical constituents to the bottom waters has the potential to interfere with and possibly reduce phosphate removal efficiency (Metcalf and Eddy 1991).

Flux of phosphorus from sediments to the water column is greater under anaerobic conditions (Haggard and Soerens 2006). Lake Tenkiller stratifies during the summer months resulting in hypoxia and anoxia in the hypolimnion. Connolly (2009) estimates the hypolimnetic SRP mass increases by approximately 3,000 kg during the summer due to sediment release under anaerobic conditions. However, as noted by Cooke et al. (2005), vertical phosphorus entrainment must occur in order for sediment phosphorous release to the hypolimnetic lake water to affect algal production. Temperature profiles of Lake Tenkiller indicate that mixing of the epilimnion and the hypolimnion does not occur until the late fall. Because the average residence time in the lacustrine portion of Lake Tenkiller is approximately seven months (Connolly 2009), the majority of hypolimnetic phosphorus introduced to the surface waters during overturn in October is flushed out of the lake before the algal growing season in the late spring.

While the Chapman et al. (2009) states that the State of Oklahoma is not proposing a specific alum treatment program for the Illinois River and Lake Tenkiller at this time, the respondents were led to believe that this treatment is a viable and proven option. However, Mr. Todd King, a consultant representing the State of Oklahoma, has stated he would not recommend alum treatment of the Illinois River system based on the current data (King deposition, Page 288 and line number 8, 2009). Neither Mr. King nor Dr. Welch, both of whom are State of Oklahoma consultants in this case, recommend alum treatment in the Illinois River or Lake Tenkiller. In fact, Mr. King even states on Page 12 of his report: "…aluminum can potentially damage aquatic ecosystems and is potentially phytotoxic to plants at low pH" (King 2008).

3.2.3 Permitting and Stakeholder Concerns

The CV Survey should have also informed the respondents about permitting requirements and concerns raised by stakeholders in other states in response to suggested alum treatment. Rather, the Survey indicated broad acceptance of alum treatment.

If an alum product makes a claim that it controls algae, then it is presumed to be an algaecide, and therefore can be regulated under the National Discharge Elimination Permit System (NDEPS; NALMS 2008). Permitting can be a long and costly process and result in significant delays and added cost (Herrera Environmental Consultants 2003; Sauk River Watershed District 2004). This was not disclosed to Survey respondents.

Alum treatment is often faced with controversy from local stakeholders due health and safety concerns for humans and the aquatic life. The Stratus Survey presents alum as safe for humans and states that during application the alum forms harmless particles in water, and

EXHIBIT P

harmless particles in the soil (Chapman et al. 2009). This statement minimizes and ignores stakeholder concerns with alum treatments which can impact acceptance and project completion. For instance in 2006, a newspaper report on treating Honeoye Lake in New York with alum recognized that alum treatment was an imperfect solution and reported that two nearby cities shelved plans to pursue alum treatment. Plans to treat Conesus Lake with alum were postponed due to controversy among fisherman and the $1.3 million price tag and a project to treat Sodus Bay encountered trouble with state environmental permits and the project was abandoned (Edgcomb 2006).

In 2007, Long Pond, a 740-acre pond located between the towns of Harwich and Brewster, MA, was treated with 82,000 pounds of alum in an attempt to remediate its phosphorus problem. However, the decision to proceed with the alum treatment came after six years of discussions amongst interested parties. There is continuing concern that source loadings of phosphorus were not addressed and in time, phosphorus levels will build again, necessitating further alum treatments and possibly further controversies (Tunney 2006, 2007).

Stakeholder involvement and permitting processes must be considered in recommending any remedy in the Illinois River Watershed as both can greatly impact the definition and progress of a remedy. Survey respondents should have been told that stakeholder involvement is generally encouraged, permitting is likely to be required, and that the alum treatment could be a long, drawn out effort and not the quick fix that was presented.

4 ALUM APPLICATION TO SOILS IN THE ILLINOIS RIVER WATERSHED

The following are factors to consider when assessing the efficacy of applying alum to soils for the purpose of reducing phosphorus transport from grass pastures to surface water bodies.

Alum is the common name for a dry solid mineral material with the chemical formula: $Al_2(SO_4)_3$ $18H_2O$. Alum is commonly applied to soil in the production of specific horticultural crops as a method to increase soil acidity and, therefore reduce soil pH, in situations where horticultural crop productivity will be enhanced by increased soil acidity. Typically, purposeful acidification of the soil involves thorough incorporation of the applied alum into the soil rooting volume.

Typically, mineral soils located in the southeastern United States are acidic (pH<7). It is common practice to apply agricultural limestone (e.g., "lime" or $CaCO_3$) to grass pastures to neutralize naturally occurring soil acidity and maintain elevated soil pH in a suitable range for optimum forage production (pH 5.5 to 6.5). Agricultural limestone (increases pH) and alum (decreases pH) have opposite affects on soil acidity.

Application of alum to grass pastures in the Illinois River Watershed has the potential to increase soil acidity (decrease soil pH) to levels detrimental to forage grass production. The degree and duration of soil acidification due to surface application of alum will be highly dependent on soil physical and chemical properties, soil organic matter, rainfall, as well as past and future land management decisions. Multiple applications of agricultural limestone over multiple years may be necessary to neutralize soil acidification resulting from alum applications. The need for such lime applications will impose a financial burden on farmers in the Illinois River Watershed unless funds are made available to farmers to offset this additional expense. In essence, farmers who have land applied poultry litter to their pastures in an environmentally responsible fashion may be required to finance an unknown number of future lime treatments to their pastures in order to mitigate the detrimental soil acidification caused by the proposed alum treatment. Respondents were not told about this expected soil acidification or who would pay for it. Respondents were told (Chapman et al. 2009, Page 4-20) that:

Putting alum on the land and in the water would have some undesirable effects

But the only undesirable effect to the land that the respondents were told about was that:

The alum would be a white powder on the land surface until rains carry it down into the soil

Plaintiffs' characterization of the undesirable effects of alum treatment of pasture land as being limited to the presence of a white powder on the land surface for a short period of time, with no mention of the soil acidification that would occur in response to the treatment, was irresponsible. Respondents were not given an accurate description of potential adverse impacts.

Perhaps if respondents had been told that the alum treatment would acidify farmers' pasture soils, requiring a liming program of unknown duration and unknown cost to mitigate the damage to pasture soils, the respondents might have answered differently.

Decreased forage grass productivity due to soil acidification can impact pasture carrying capacity and beef cattle productivity. Alum applications that increase soil acidity to the point of creating toxic conditions for forage grass growth may result in a thinning or elimination of the forage plants in the pasture. Denuded areas in a pasture are subject to rainwater erosion and accelerated transport of sediment and soil nutrients off of the site.

Aluminum toxicity to plant roots is exacerbated when soil pH declines below 5.0 due to the increasing domination of the toxic Al^{3+} species among the various soil Al hydrolysis products. Even Plaintiffs' own consultant, Todd King (2008, Page 12) acknowledged that aluminum:

Is potentially phytotoxic to plants at low pH

Different plant species have different levels of tolerance to soil acidity and free Al^{3+} concentration in the root zone. Research with three Washington County, Arkansas, soils

EXHIBIT P

that had a history of poultry litter applications demonstrated that applying alum to soil at a 2:1 molar ratio of alum Al:soil total P resulted in decreasing soil pH from 6.07 to 3.80, 5.95 to 3.71, and 6.42 to 4.00, respectively for each of the three soils (Miller et al. 1994). For all three of the soils studied, soil pH was decreased from ideal conditions to toxic conditions by the alum additions. Simultaneous co-application of calcitic limestone ($CaCO_3$) at approximately 1:3 total mass ratio to the alum application rate was necessary in order to maintain soil pH at the lower limits of the acceptable range for forage grass production (pH=5.74, 5.57 and 5.42, respectively) (Miller et al. 1994).

The proposed plan for large-scale, wide-spread application of alum to privately owned grass pastures is highly unusual, and may be a completely unique proposition. Stratus did not address whether alum application to privately owned pastures would be compulsory or voluntary. Stratus did not provide an implementation plan or discuss the authority for requiring alum application to privately owned lands. If the proposed alum application to privately owned pastures was intended to be voluntary, a projected rate or extent of voluntary adoption of this practice should have been presented to survey respondents. The theory behind the proposed plan is that alum application to soils can convert soluble soil phosphorus (P) to insoluble Al-P precipitates such as the mineral veriscite, $AlPO_4$. The conversion of soluble soil P to solid-phase mineral P in the surface soil layers may decrease the potential for soluble P transport with field drainage water, if surface runoff water is generated from the soil.

Plaintiffs own consultant, Todd King (2008, Page 12), in discussing the proposed potential treatment of fields and pastures in the Illinois River Watershed with alum, stated the following:

> *However, the effectiveness of alum in immobilizing P in-situ to fields and pastures as found within the IRW has not been demonstrated on a large-scale basis. For this reason, this technology requires additional investigation and assessment.*

Because the solution proposed by Stratus to the survey respondents was based on a chemical treatment that was not proven, was in need of additional investigation, and was potentially costly to landowners and counterproductive to pasture productivity and farm profitability, the results of the survey with respect to willingness-to-pay are invalid.

Research has demonstrated that application of alum at a 1:1 molar ratio of applied alum Al:soil total P to three Arkansas soils with relatively high levels of soil total P resulted in maximum reduction in soil soluble P concentrations (Miller et al. 1994). This same research also demonstrated that doubling the alum application rate resulted in increased soil soluble P because soil pH decreased below 4.0 and greatly increased the solubility of Al-P solid materials in the soil (Miller et al. 1994). Clearly, precise alum application rates and prior site-specific knowledge of soil total P concentrations are critical in order to avoid inadvertent elevation of soil soluble P concentrations resulting from alum applications that were intended to decrease soil soluble P concentrations. Under field conditions, the rate of chemical reaction of alum in the soil that generates soil acidity is expected to be significantly faster than the rate of chemical reaction of agricultural limestone in the soil that neutralizes soil acidity. Therefore, not only will there be a need for precise site-specific balancing of the quantities of alum and limestone added to the soil, as discussed above, there also will be a need for precise timing of the two off-setting chemical reactions of these two amendments. The optimal timing of the land application of limestone relative to the land application of alum is unknown. A mismatch between the application rates of alum relative to soil total P or a mismatch between application timing of alum relative to limestone application may result in severe soil acidification, an elevation in soil soluble P, a decline in forage grass yield and decreased beef cattle productivity. The extraordinary level of management and situational control that would be required to achieve the necessary site-specific application rates and timing requirements outlined above would be extremely unlikely in the real world. If soil pH is maintained within the recommended range by application of agricultural limestone, alum application to soils may decrease plant available P concentrations and may induce P nutritional deficiencies in the forage grasses resulting in decreased forage yield and pasture productivity.

Soils are not uniform within a single pasture or among multiple pastures. As thoroughly described in the expert report of Dr. Frank J. Coale (November 26, 2008), the potential for P transport from a production field to a surface water body is highly site specific. Multiple site-specific characteristics must be evaluated to determine the potential for P transport from a pasture. Likewise, the expected impact of any given alum application rate will be variable across a pasture or among multiple pastures due to differences in soil physical and chemical characteristics and site hydrologic properties. Effective alum application rates must be determined on a site-specific basis at the field or sub-field level. Corresponding corrective lime application rates must also be determined on a site-specific, field by field basis. These essential site-specific management requirements add substantial complexity to the farm management decision making process. A field-by-field assessment of the effectiveness of proposed alum applications must be determined before any universal, one-size-fits-all remediation plan is implemented.

The prescribed rate of alum application must be determined on a site-specific basis depending on soil total P concentrations, which vary within and among pasture fields. Precisely uniform field application of alum to production pastures is very difficult and not practically achievable. If co-application of agricultural limestone is prescribed with alum amendments, the required precise and uniform application of limestone will be difficult to achieve.

The proposed Stratus "solution" of applying alum to pasture lands throughout the Illinois River Watershed has not, to the best of our knowledge, been established by anyone on the Plantiffs' team of scientific consultants as being reasonable, responsible, or effective in achieving its intended purpose: reducing the transport of P from pasture soils to surface water bodies. Furthermore, the potential negative effects of such an alum treatment of pasture lands, including soil acidification and potentially an increased mitigation costs to farmers, were not evaluated or communicated to survey respondents. Therefore, survey results based on such a "solution" are invalid.

EXHIBIT P

5 REFERENCES

Baird, R. 1987. *A Preliminary Assessment of Phosphorus precipitation-Inactivation as a Restoration Technique in Lake Apopka.* Prepared for St. Johns River Water Management District.

Bierman, V.J. 2009. Expert Report of Victor J. Bierman, Jr., Janauary 23, 2009. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-0329-GFK-SAJ.

Branfireun, B.A., N.T. Roulet, C.A. Kelly, and J.W.M. Rudd. 1999. In Situ sulphate stimulation of mercury methylation in a boreal peatland: toward a link between acid rain and methylmercury contamination in remote environments. *Global Biogeochem. Cycles* 13: 743–750.

Chapman, D.J., R.C. Bishop, W.M. Hanemann, B.J. Kanninen, J.A. Krosnick, E.R. Morey, and R. Tourangeau. 2009. *Natural Resource Damages Associated with Aesthetic and Ecosystem Injuries to Oklahoma's Illinois River System and Tenkiller Lake.* Expert Report for State of Oklahoma, in Case No. 05-CV-0329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Volume I.

Connolly, J.P. 2009. Expert Report of John. P. Connolly, Ph.D., P.E., BCEE, January 30, 2009. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-0329-GFK-SAJ.

Cooke, G.D., and E.B. Welch. 2008. Expert Report of G. Dennis Cooke, Ph.D., and Eugene B. Welch, Ph.D., June 6, 2008. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-0329-GFK-SAJ.

Cooke, G.D., E.B. Welch, S.A. Peterson, and P.R. Newsroth. 1993. *Restoration and Management of Lakes and Reservoirs.* Boca Raton: Lewis Publishers. Second Edition.

Cooke, G.D., E.B. Welch, S.A. Peterson, and S.A. Nichols. 2005. *Restoration and Management of Lakes and Reservoirs.* Boca Raton: Lewis Publishers. Third Edition.

Coale, F. 2009. Expert Report of Frank Coale, Ph.D., January 15, 2009. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-0329-GFK-SAJ.

Edgcomb. M. 2006. *Slimy, stinky algae in Honeoye Lake.* Rochester Democrat and Chronicle. http://www.democratandchronicle.com/apps/pbcs.dll/article?AID=/20060803/NEWS01/608

Engel, B. 2008. Expert Report of Bernard Engel, Ph.D., P.E. May 14, 2008. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-0329-GFK-SAJ.

Fish and Wildlife Research Institute. 2005. *Largemouth Bass Virus (LMBV) and Its Effects on Largemouth Bass Resources in Florida.* http://research.myfwc.com/features/view_article.asp?id=28302.

Fisher, J.B. 2008. Expert Report of J. Berton Fisher, Ph.D., CPG, RPG. May 15, 2008. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-0329-GFK-SAJ.

Grip, W.M. 2008. Statement of Opinions of Wayne M. Grip, October 2008. State of Oklahoma, et al. v. Tyson Foods, Inc., et al., Case No. 4:05-CV-00329-GFK-SAJ

Haggard, B.E. and T.S. Soerens. 2006. Sediment phosphorus release at a small impoundment on the Illinois River, Arkansas and Oklahoma, USA. *Ecological Engineering* 28: 280-287.

Hart, R. P. 2007. Summary of ENSR Report Findings & Recommendations.

Harvey, H.H., and D.A. Jackson. 1995. Acid stress and extinction of a spring-spawning fish population. *Water, Air, & Soil Pollution* 85: 383-388.

Herrera Environmental Consultants. 2003. Green Lake Alum Treatment Study. Prepared for Seattle Department of Parks and Recreation.

Horne, A. 2009. Expert Report of Alex Horne, January 30, 2009. State of Oklahoma, et al. v. Tyson Foods, Inc., et al., Case No. 4:05-CV-00329-GFK-SAJ.

Jarman, R.L. 2008. Expert Report of Ron L. Jarman, Ph.D. December 1, 2008. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-329-GFK-SAJ.

Kerry, A., P.M. Welbourn, B. Prucha, and G. Mi. 2004. Mercury methylation by sulphate-reducing bacteria from sediments of an acid stressed lake. *Water, Air, and Soil Pollution* 56: 565-575.

EXHIBIT P

King, T.W. 2008. *Identification and Evaluation of Viable Remediation Alternative to Address Injuries related to Land Disposal of Poultry Waste within the Illinois River Watershed.* Prepared May 15, 2008.

Larson, J. July 2008. Wapato Lake fish kill ‘not the promised outcome. *Tacoma Weekly*. http://www.tacomaweekly.com/article/2168/.

Lawler, D. 2006. *Physical and Chemical Treatment Processes for Waste and Wastewater*. Austin: Copyright Clearance Center, Inc.

Lewandowski, J., I. Schauser, and M. Hupfer. 2003. Long term effects of phosphorus precipitations with alum in hypereutrophic Lake Susser See (Germany). *Water Research* 37: 3194-3204.

Litke, D.W. 1999. *Review of Phosphorus Control Measured in the United States and Their Effects on Water Quality*. United States Geological Survey.

McCormick, H., M.J. Kathleen, and L.E.Anderson. 1989. Chronic effects of low ph and elevated aluminum on survival, maturation, spawning and embryo-larval development of the fathead minnow in soft water. *Water, Air, & Soil Pollution* 43: 293-307.

Metcalf and Eddy, Inc. 1991. *Wastewater Engineering, Treatment Disposal Reuse.* New York: McGraw-Hill.

Miller, D.M., P.A. Moore, Jr., T.C. Daniel, D.R. Edwards. 1994. *Phosphorus immobilization in poultry litter and litter-amended soils with aluminum, calcium and iron amendments.* Research Project Technical Completion Report, Arkansas Water Resources Center, Publication No. 169, Fayetteville, Arkansas. 51 pages.

Narf, R.P. 1990. Interactions of Chironomidae and Chaoboridae (Diptera) with aluminum sulfate treated lake sediments. *Lake Reservoir Manage.* 6:33-42.

North American Lake Management Society (NALMS). July 2008. Affiliate talk: Alum treatment. http://www.nalms.org/Publications/NALMSNotes/notes08-7.html.

North American Lake Management Society (NALMS). February 2004. NALMS Position Paper – Statement 2: The Use of Alum for Lake Management.

NALMS. 2003. *Proceedings of the 12th Annual North American Lake Management Society Southeastern Lakes Management.* Orlando-Kissimmee Hyatt, Orlando, Florida, June 2-5, 2003.

Olsen, R.L. 2008. Expert Report of Roger L. Olsen, Ph.D. July 25, 2008. State of Oklahoma et al. v. Tyson Foods, Inc., et al., Case No. 05-CV-0329-GFK-SAJ.

Princeton Hydro, LLC. 2005. *Alum Bench Test Results Honeoye Lake.* Prepared for Honeoye Valley Association, Honeoye, New York.

Rocco, G.L., and R.P. Brooks. 2000. *Abundance and Distribution of a Stream Plethodontid Salamander Assemblage in 14 Ecologically Dissimilar Watersheds in the Pennsylvania Central Appalachians.* Prepared for U.S. Environmental Protection Agency, Region III.

Sauk River Watershed District. 2004. Osakis Lake Watershed Management Project Continuations: Final Report.

Smeltzer, E. 2006. The *Lake Morey Alum Treatment: Looking Back after 20 Years.* Prepared for the Vermont Department of Environmental Conservation. http://www.uvm.edu/~seagrant/communications/assets/LakeMorey.ppt#259,1,The%20Lake%20Morey%20Alum%20Treatment:%20Looking%20Back%20After%2020%20Years

Steinman, A.D., and M. Ogdahl. 2008. Ecological effects after an alum treatment in Spring Lake, Michigan. *J. Environ.Qual* 37:22-29.

Stevenson, R.J. 2008. Nutrient Pollution of Streams in the Illinois River Watershed, Oklahoma Effects on Water Quality, Aesthetics, and Biodiversity. Expert Report of Dr. R. Jan Stevenson, State of Oklahoma v. Tyson Foods, et al., Case No. 05-CU-329-GKF-SAJ.

Sullivan, T.J. 2009. Expert report, State of Oklahoma et al. vs. Tyson Foods et al., United States District Court for the Northern District of Oklahoma, 230 pp.

Summers, P.B. 1961. Observations on the Limnological Dynamics of Tenkiller Ferry Reservoir. Oklahoma Department of Wildlife Conservation, Federal Aid Division, OWRB-025-0002035.

Tetra Tech. 2007. *Management of Wapato Lake Quality: Interim Project Status Report.*

EXHIBIT P

Tunney, D. 2007. Alum for Long Pond? *Harwich Oracle*, MA. January 17, 2007. http://www.wickedlocal.com/harwich/homepage/x1878159190

Tunney, D. 2006. Pondering Long Pond. *Harwich Oracle*, MA. April 25, 2006. http://www.wickedlocal.com/harwich/archive/x1563283703

URS. 2006. *A Summary Report of the Silver Lake Water Quality Management Alum Treatment Feasibility Study.* October 2006. http://www.cityofdover.com/media/exhibits.

Water and Air Research, Inc. 1999. Investigation on the effect of alum treatment on benthic invertebrate communities of Florida Lakes. Prepared for St. Johns River Water Management District.

Wisconsin Department of Natural Resources (WDNR). 2003. Alum Treatments to Control Phosphorus in Lakes.

EXHIBIT P

FIGURES

EXHIBIT P

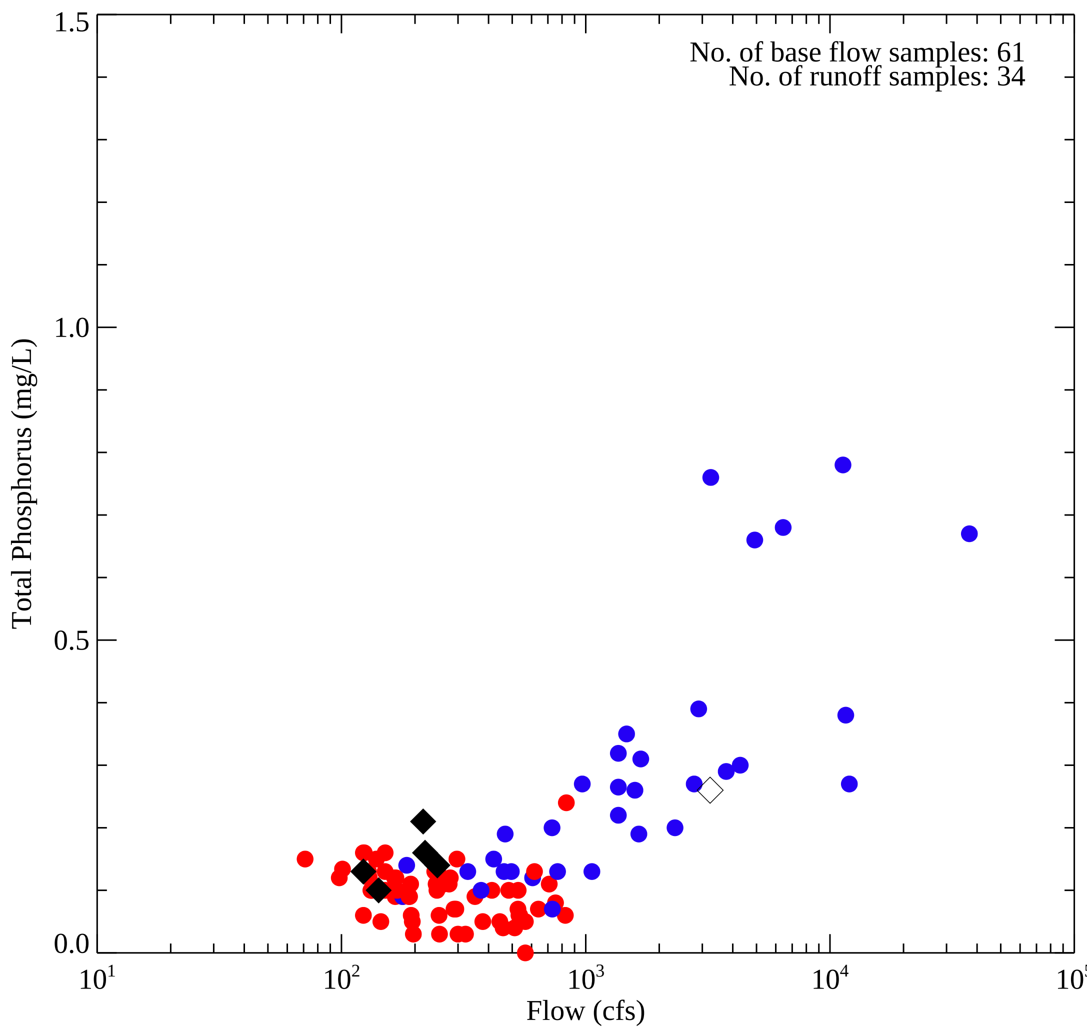

Figure 2-1. Total phosphorus concentrations as a function of flow at Watts.

Base flow conditions are days when base flow is 70% or greater of total flow.
Data: USGS 1969, 2004 - 2008, Plaintiffs Database 2004-2008, OWRB 2004 - 2008.

Base Flow
Runoff
Base Flow (1969)
Runoff (1969)

RN - \\Raghav\d_drive\OICiln\OICiln_160\tp_rating_curve_watts.pro
Mon Mar 23 17:24:13 2009

EXHIBIT P